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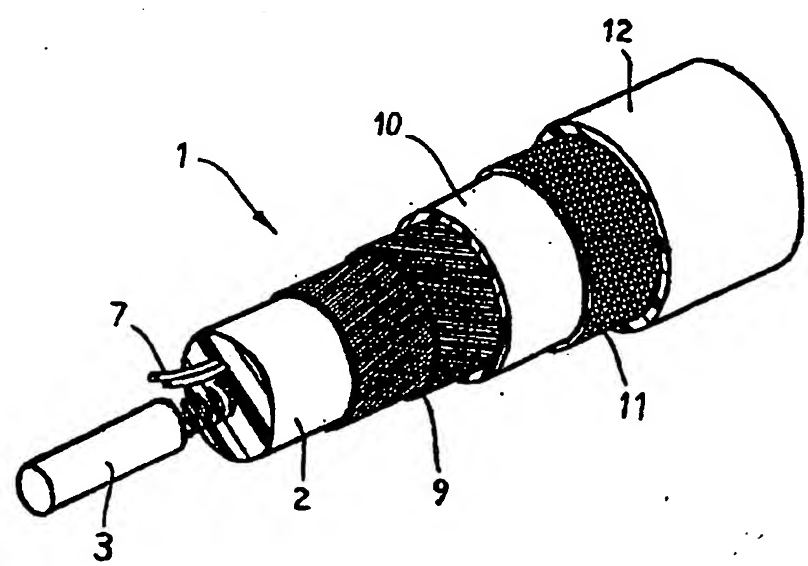


(57) Abstract

A sensor cable (1) comprises an inner core (2) including an array of sensors (3), conductors (7) which are connectible between the sensors and remote receiving, monitoring and/or processing apparatus, and an outer sheath (12), in which the conductors are connected to a conductor harness (9) extending along the cable between the inner core and the outer sheath. For use on the sea-bed, the conductor harness and the outer sheath form concentric layers around the core, which may be formed from a castable polyurethane. For use in towing in the water, the core may be formed from polyurethane containing microballoons and the outer sheath may be filled with water or other aqueous medium, conveniently sea-water.

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# SENSOR CABLE

The present invention relates to sensor cables and is particularly concerned with a cable of the type comprising an inner core including an array of sensors, conductors which are connectible between the sensors and remote receiving, monitoring and/or processing apparatus, and an outer sheath. Such cables will be referred to herein as sensor cables.

Sensor cables of the aforesaid type are used, for example, in underwater geophysical exploration and monitoring. In one manner of such use, a sensor cable is laid directly on the sea bed or buried in a trench in the sea bed to collect and transmit data from pressure waves reflected from subsurface structures. Such cables are typically made up from continuous cable lengths of 3 Km or more and required to be left in place for a period of years or may be required to be picked up and relaid many times by standard winching equipment. In another manner of use, sensor cables are towed through the water, typically at a depth of 10 to 12 metres, and are equipped with vanes or flights for control purposes.

In sensor cables available until now, the conductors of the sensors are passed through the outer sheath, at a series of break-outs spaced along the length of the cable, for connection to external conductors leading to the remote apparatus. Although the break-outs are sealed, they nevertheless compromise the integrity of the cable and result in protrusions on the outer surface of the cable which are prone to damage during laying and retrieval of the cable and which reduce the overall length of cable that can be stored, for example, on a reel.

The present invention aims to overcome these drawbacks.

Accordingly, the present invention provides a sensor cable of the aforesaid type, in which the conductors of the sensors are connected to a conductor harness extending along the cable between the inner core and the outer sheath. Thus, the cable of the invention has a substantially uniform cross-section along its length, enabling the cable to be handled without risk of damage and maximising the length of cable that can be stored on a reel.

In a first embodiment, typically for disposition on the sea-bed and therefore requiring a negative buoyancy, the conductor harness and the outer sheath form concentric layers around the inner core, the conductor harness being formed from one or more layers of conductors laid up on the inner core and connected to the sensor conductors at intervals along the length of the core. The inner core may be formed in continuous sections incorporating sensors or arrays of sensors at intervals therealong but, because the distance between the regions of the core containing the sensors or arrays of sensors will in most cases be greater than the lengths of those regions, the inner core preferably comprises shorter sections containing respective sensors or arrays of sensors and longer blank sections between the sensor sections, the sensor sections and the blank sections having interengageable connectors at their ends so that they can be joined end to end to build up the core. Break-outs for the sensor conductors connectible to the harness are preferably formed intermediate the ends of each sensor section.

The sensor sections are preferably made from a castable polyurethane or other plastics material which can be cast

around the sensors or arrays of sensors at a temperature low enough to avoid thermal damage to the sensors. The blank sections, on the other hand, are preferably made from extrudable polyurethane or other plastics material, which is less expensive and less time-consuming to use for the production of longer sections than the castable material of the sensor sections. Other suitable materials may however be used for the sections of the inner core.

To avoid degradation of or damage to the sensors caused by shear waves travelling along the cable structure, the sensors may be encapsulated in a material of low shear strength before they are incorporated in the inner core. Acoustic sensors encapsulated in this manner have an enhanced response to direct acoustic pressure waves, in comparison with unencapsulated sensors, and are isolated from the shear waves which may travel along the cable structure in use. Preferably, each sensor is encapsulated in a respective, discrete body or "slug" of low shear strength material which is moulded around the sensor prior to its incorporation in the inner core. In this embodiment, the conductors of the sensors project from the bodies or slugs for connection to the conductor harness. The low shear strength material is preferably a polyurethane gel.

In addition to the inner core being formed in sections, the conductor harness may be formed in sections which are connected together before the outer sheath is formed over the entire length of the cable; in some cases, however, the outer sheath may also be formed in sections, the respective connections between the sections of the inner core, the sections of the harness and the sections of the outer sheath preferably being offset longitudinally relative to one another so that they do not coincide and

form zones of weakness.

In the first embodiment, the conductor harness is preferably covered by an intermediate sheath and, in some cases, an armour braid may be interposed between the intermediate sheath and the outer sheath while, in other cases, the outer sheath itself may be constituted by at least one layer of armour wire. In the latter case, the outer sheath is preferably formed by the layers of armour wire wound helically in opposite sense for torsional balancing and, when the cable contains acoustic sensors, is free-flooding to enhance the acoustic coupling between the sensors and the exterior.

In a second embodiment, typically for towing through the water and thus requiring an effectively neutral buoyancy, the inner core is immersed in a fluid which fills the outer sheath and the conductor harness comprises a cable which extends through the fluid alongside or around the core and to which the sensor conductors are connected at intervals along the core. The purpose of the fluid filling is to prevent the outer sheath from collapsing and therefore to prevent physical damage to the sensors when the cable is wound on a reel. The core is preferably formed in sections having terminal connectors for the fluid-tight interconnection of adjoining sections and the sensor conductors break out through the connectors for connection to the harness cable. The sensor conductors may be connected to conventional telemetry pots at the junctions between adjoining sections of the core, the pots being connected to the harness cable.

The cable of the second embodiment may include spacer members for centring the inner core relative to the outer sheath. Preferably, the spacer members are formed

integrally with the inner core (which may be made from castable polyurethane or other plastics material as in the first embodiment) and also serve to locate the harness cable. The spacer members may have apertures for the passage of any power cables or strengthening elements which may extend through the fluid-filled outer sheath beside the inner core. To achieve neutral buoyancy, the inner core material may be treated to reduce its specific gravity, for example by being foamed or by incorporation of microballoons - that is, hollow glass beads of microparticle size - thereby enabling the fluid filling to be aqueous, for example sea-water, which is environmentally beneficial compared with conventional filling liquids chosen to have a specific gravity less than that of sea-water, such as kerosene.

Preferably, the inner core is of circular cross-section in the first embodiment and of square cross-section in the second embodiment. In the first embodiment, however, the inner core may be of octagonal cross-section and be covered by a rounding sheath prior to the laying up of the conductor harness on the core. The rounding sheath may be formed around sensor conductors which have been brought of out of the inner core and project therefrom or it may be cut after formation to form a series of break-outs for conductors brought out of the core and exposed on one of the flat faces thereof; in the latter case, the rounding sheath may be of a translucent material, such as extruded polyurethane, so that the exposed conductors are visible through the sheath.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cut-away perspective view of a piece of

sensor cable according to a first embodiment of the invention;

Figure 2 is a longitudinal section of a portion of the inner core of the cable according to the first embodiment;

Figure 3 is a partially-sectioned perspective view of a piece of sensor cable according to a second embodiment of the invention; and

Figure 4 is a partial longitudinal sectional view of a portion of a sensor cable in which the sensors are encapsulated in a material of low shear strength.

With reference to Figures 1 and 2, a sensor cable according to a first embodiment of the invention, generally indicated 1, comprises an inner core 2 of circular section which includes a longitudinal array of sensor units 3, such as hydrophones and their associated pre-amplifier circuitry. The core 2 is made up of shorter sections 2A, typically 0.6m long, which incorporate respective arrays of sensors 3, and longer blank sections 2B, which may be up to 49m long, between the sections 2A. Each sensor section 2A of the core 2 is moulded around its respective array of sensors 3 from a castable polyurethane which can be cast at a relatively low temperature in order to avoid heat damage to the sensors 3 and their associated circuitry. The blank sections 2B are made from extrudable polyurethane which is cheaper and quicker to use for the production of the longer sections 2B than the castable polyurethane of the sensor sections 2A. The adjoining sections 2A, 2B of the core 2 are connected together end to end by means of interengageable terminal connectors 4, 5.

As shown in Figure 2, the blank sections 2B of the inner core 2 incorporate strain-relieving cables or wires 6 which extend axially between the connectors 5 at the ends of the sections 2B.

The wires or conductors 7 which supply power to and transmit the signals produced by the sensors 3 are brought through the inner core 2 at the midpoint of each sensor section 2A to form a plurality of break-outs, one of which is indicated 8 in Figure 2, at intervals along the inner core 2. Each break-out 8 may comprise several data channels.

The inner core 2 is surrounded by a harness 9 formed, in the illustrated embodiment, from two layers of electrical conductors, for example mini-quad cables. the number of layers in the harness 9 may vary from that shown in dependence on the number of data channels required. The harness 9 is laid up on the inner core 2 and, at intervals, the laying-up process is interrupted while the relevant conductors of the harness 9 are connected to a respective conductor break-out 8 from the inner core 2 and laying-up is then continued until the next break-out 8.

The interstices of the conductor harness 9 are packed with evacuated petroleum jelly (not shown) or other material suitable for elimination of air gaps and for enhancing the acoustic coupling between the sensors and the exterior. The harness 9 may be wrapped in tape, for example, a Mylar tape, to hold it in place.

The harness 9 is surrounded by an intermediate sheath 10 of extruded polyurethane and an armour braid 11 of stainless steel is laid over the intermediate sheath 10 to give the cable tensile strength and mechanical

protection.

Finally, the armour braid 11 is covered by an outer sheath 12 of extruded high-grade polyurethane.

When the cable 1 is complete, the conductors of the harness 9 project from one end of the cable for connection to apparatus (not shown) for receiving, monitoring and/or processing the data collected by the hydrophones or other sensors.

The completed cable 1 is circular in section, with the sheaths 10 and 12, the harness 9 and the braid 11 disposed concentrically with respect to the core 2. In the embodiment illustrated in Figures 1 and 2, the inner core 2 has a diameter of about 33mm and the external diameters of the harness 9, the intermediate sheath 10, the braid 11 and the outer sheath 12 are of the order of 39mm, 45mm, 51mm and 56mm, respectively.

With reference to Figure 3, a sensor cable according to a second embodiment of the invention, generally indicated 21, comprises an inner core 22 and an outer sheath 23, as in the first embodiment, but the core 22 is immersed in an aqueous fluid 24 which fills the sheath 23. The core 22 is of square cross-section and is formed in sections which incorporate respective sensors (not shown) and which are interconnected in a fluid-tight manner by terminal connectors 25. The core 22 is made from castable polyurethane containing microballoons of specific gravity approximately 0.6, whereby the entire cable is of neutral buoyancy.

The wires or conductors (not shown) of the sensors break out of or emerge from the core 22 through the connectors 25 between adjoining core sections and are sealingly

connected to conventional telemetry pots, schematically indicated 26, mounted on the core 22 in correspondence with the joints formed by the connectors 25. The telemetry pots 26 are connected to a conductor harness constituted by a cable 27 which extends through the fluid 24 alongside the core 22.

The sections of the inner core 22 have integral spacers 28 in the form of transverse enlargement or protrusions which are engageable with the inner wall of the outer sheath 23 at intervals therealong to centre the core 22 relative to the sheath 23. The spacers 28 incorporate rigid inserts which serve to reinforce the spacers during handling of the cable 21 and have peripheral notches 29 which, with the sheath 23, define apertures for the passage of the harness cable 27 and any ancillary power cables, strengthening members or the like.

The connected sections of the inner core 22, the telemetry pots 26 and the harness cable 27 form a sealed unit which isolates the sensor conductors and the conductors of the harness cable 27 from the fluid 24 so that, if required, the outer sheath 23 can safely be filled with a conductive fluid.

With reference to Figure 4, a sensor cable 30 has an outer sheath 31 and an inner core 32. The outer sheath 31 is made from extruded polyurethane and is covered by wound steel armouring 37. The inner core 32 is made from castable polyurethane and is formed in sections, each of which incorporates a respective sensor 33, for example a hydrophone, and is connected to adjoining sections by terminal connectors 34. Prior to its incorporation in the respective section of the inner core 32, each sensor 33 is encapsulated in a discrete body 35 of polyurethane gel which has a low shear strength and serves to isolate

the sensor from shear waves which may travel along the cable structure when the cable is in use.

The polyurethane gel is moulded around the sensor at low temperature so as not to cause thermal damage to the sensor and the conductors 36. The conductors 36 which supply power to and transmit the signals produced by the sensor 33 emerge from the body 35 of gel for connection to a conductor harness similar to that described with reference to Figures 1 and 2 between the outer sheath 31 and the inner core 32. Conveniently, the conductors 36 break out of or emerge from the core 32 through a circumferential slot at the centre of the respective core section and are connected to the conductor harness through waterproof terminations.

It will be appreciated that, in each of the described embodiments, sensors other than geophones may be incorporated in the inner core, according to the requirements of use for which the cable is intended.

CLAIMS

1. A sensor cable comprising an inner core including an array of sensors, conductors which are connectible between the sensors and remote receiving, monitoring and/or processing apparatus, and an outer sheath, in which the conductors are connected to a conductor harness extending along the cable between the inner core and the outer sheath.

2. A sensor cable according to Claim 1, in which the conductor harness and the outer sheath form concentric layers around the inner core, the conductor harness being formed from one or more layers of conductors connected to the sensor conductors at intervals along the length of the core.

3. A sensor cable according to Claim 1 or Claim 2, in which the inner core comprises shorter sections containing respective sensors or arrays of sensors and longer blank sections between the sensor sections.

4. A sensor cable according to Claim 3, in which the respective sections have interengageable end connectors.

5. A sensor cable according to Claim 3 or Claim 4, in which the sensor sections are formed from a castable plastics material.

6. A sensor cable according to Claim 5, in which the castable plastics material is castable polyurethane.

7. A sensor cable according to any preceding claim, in which the sensors are encapsulated in a material of low shear strength before incorporation in the inner core.

8. A sensor cable according to any preceding claim, in which the conductor harness is covered by an intermediate sheath and optionally an armour braid beneath the outer sheath.

9. A sensor cable according to any of Claims 1 to 7, in which the outer sheath is formed by layers of armour wire wound helically in opposite senses and is free-flooding.

10. A sensor cable according to Claim 1, in which the inner core is surrounded by a fluid which is contained in the outer sheath, the conductor harness comprising a cable which extends through the fluid alongside or around the core and to which the sensor conductors are connected at intervals along the core.

11. A sensor cable according to Claim 10, in which the cable includes spacer members optionally formed integrally with the core for centring the core relative to the outer sheath and for locating the harness cable.

12. A sensor cable according to Claim 10 or Claim 11, in which the inner core is formed from a castable polyurethane incorporating microballoons.

13. A sensor cable according to any preceding claim, in which the sensors comprise hydrophones.

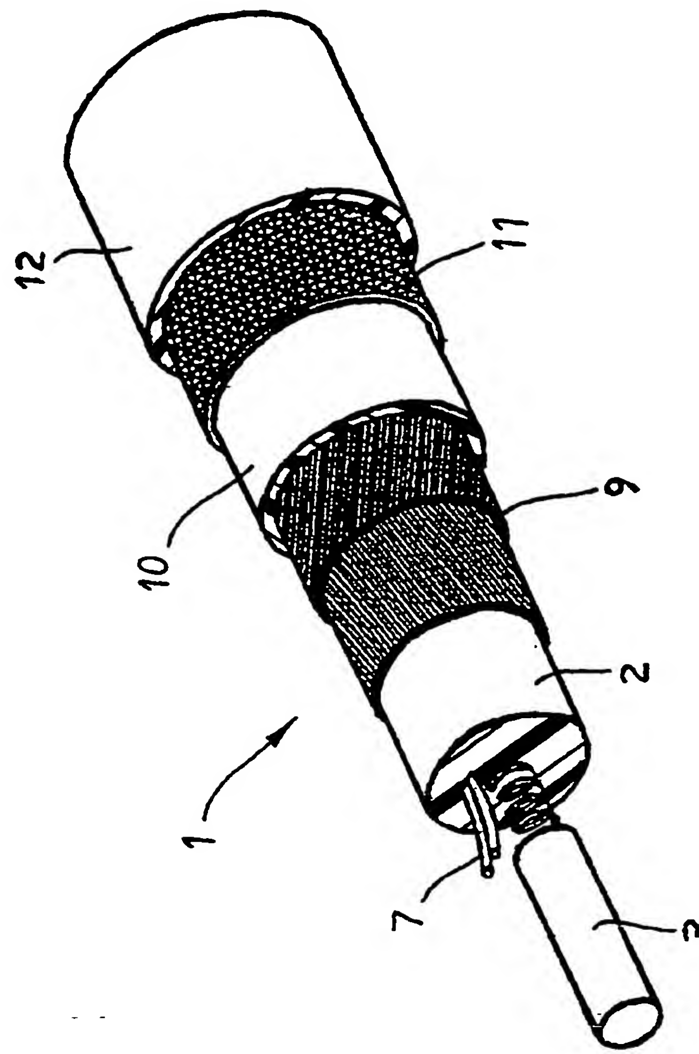


FIG. 1

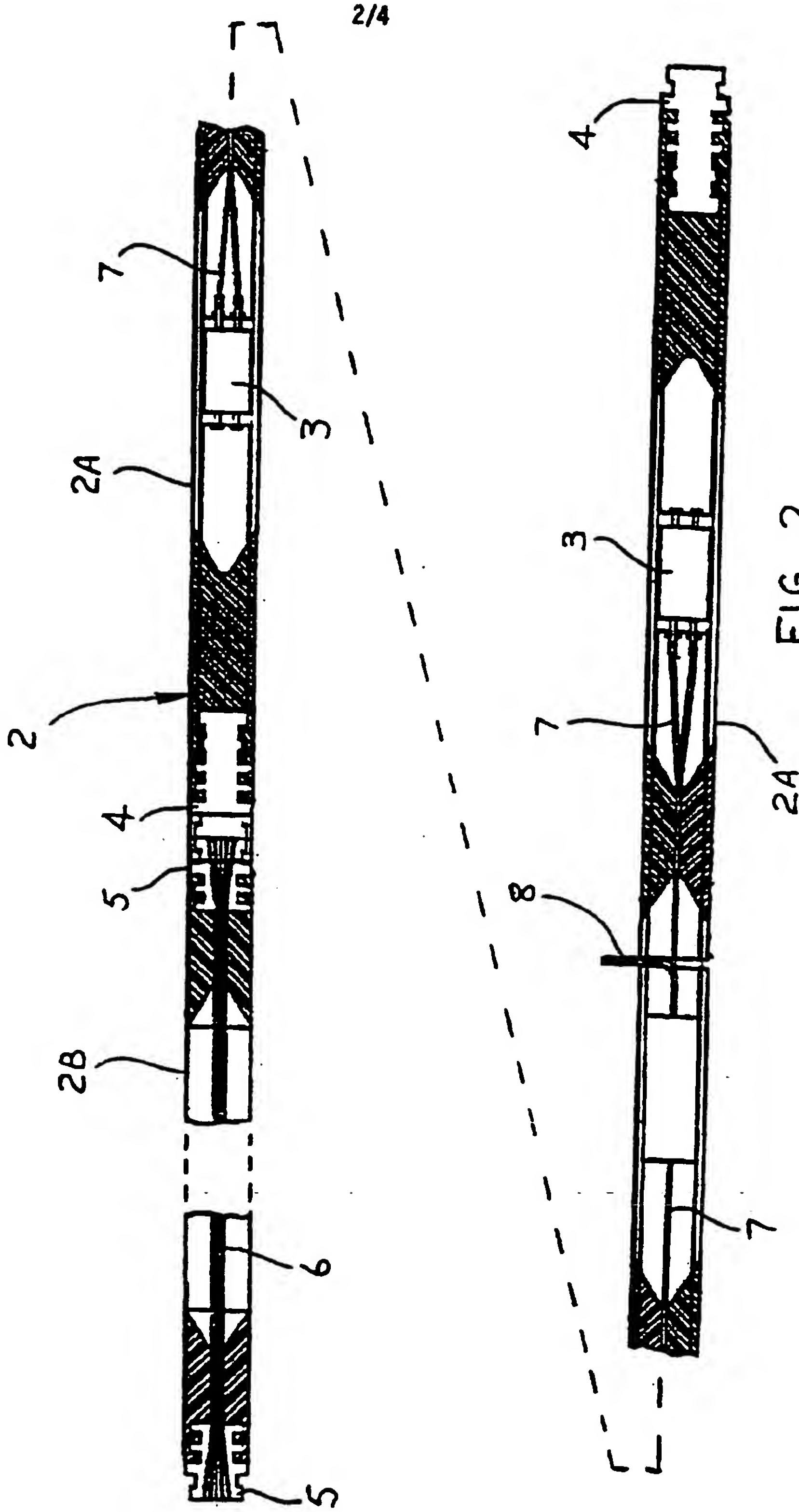


FIG. 2

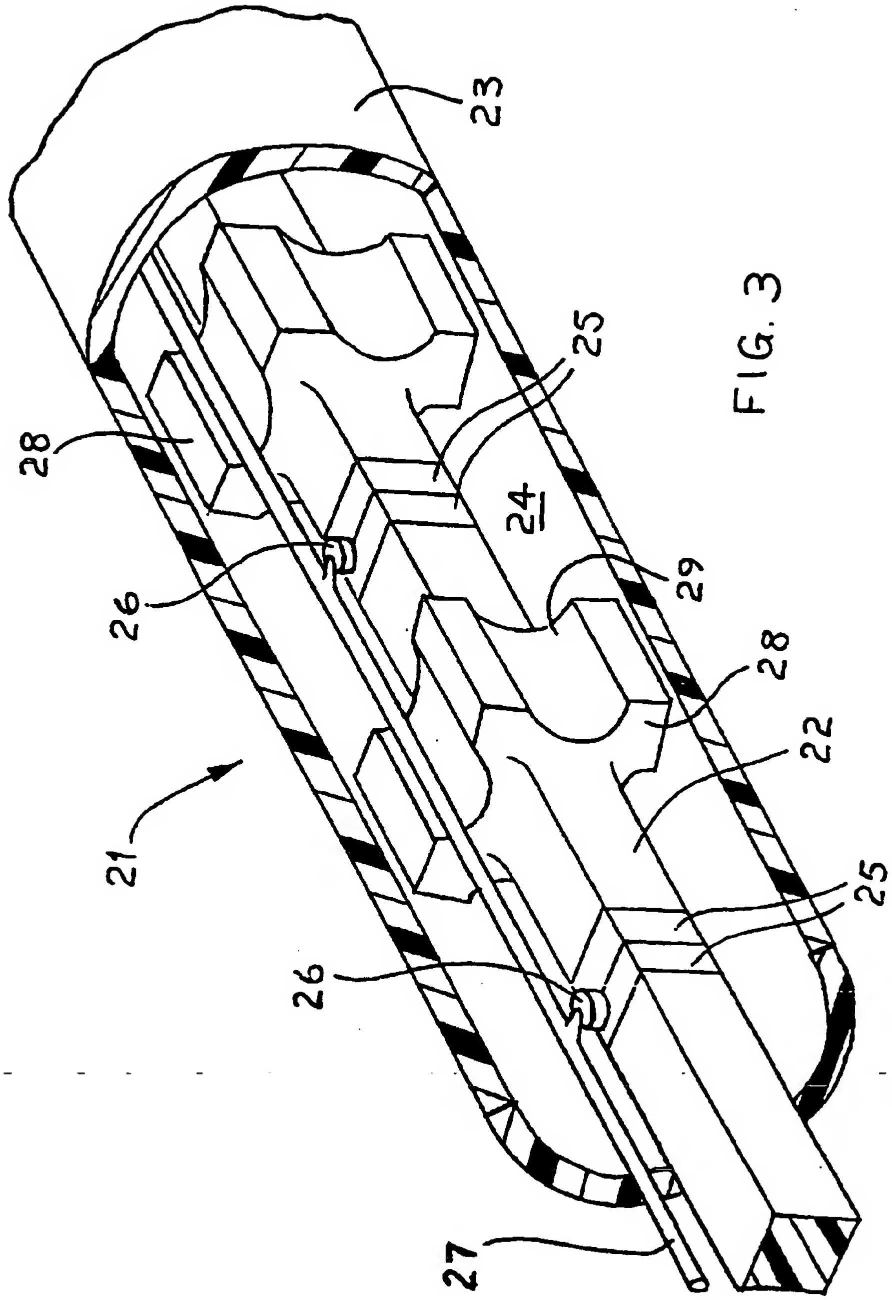


FIG. 3

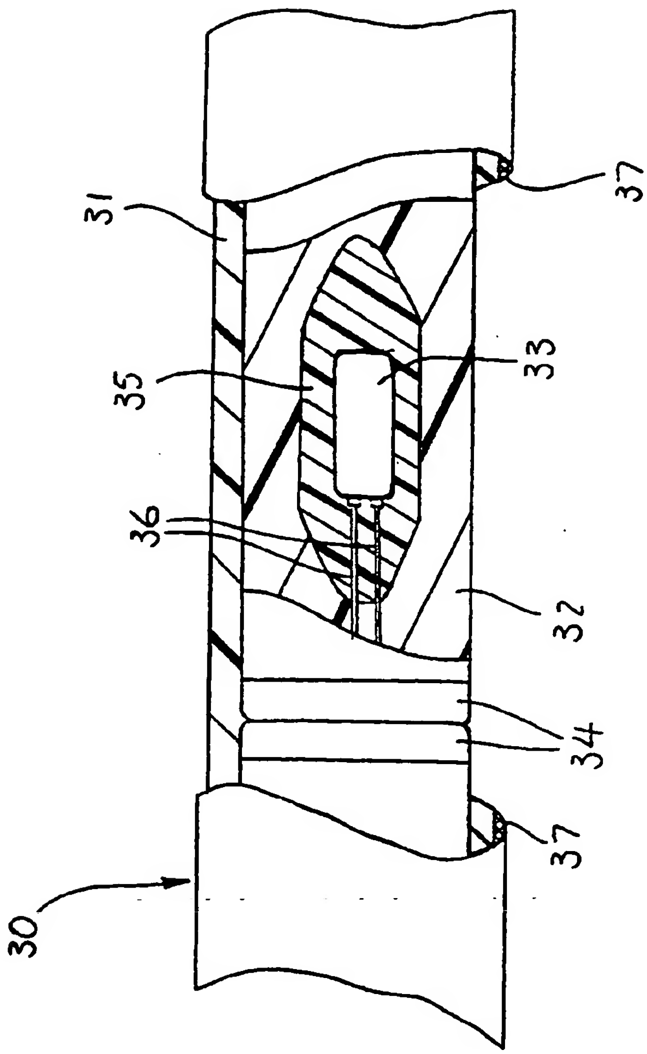


FIG. 4

# INTERNATIONAL SEARCH REPORT

Intern al Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01V1/20

According to International Patent Classification (IPC) or to both national classification and IPC

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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